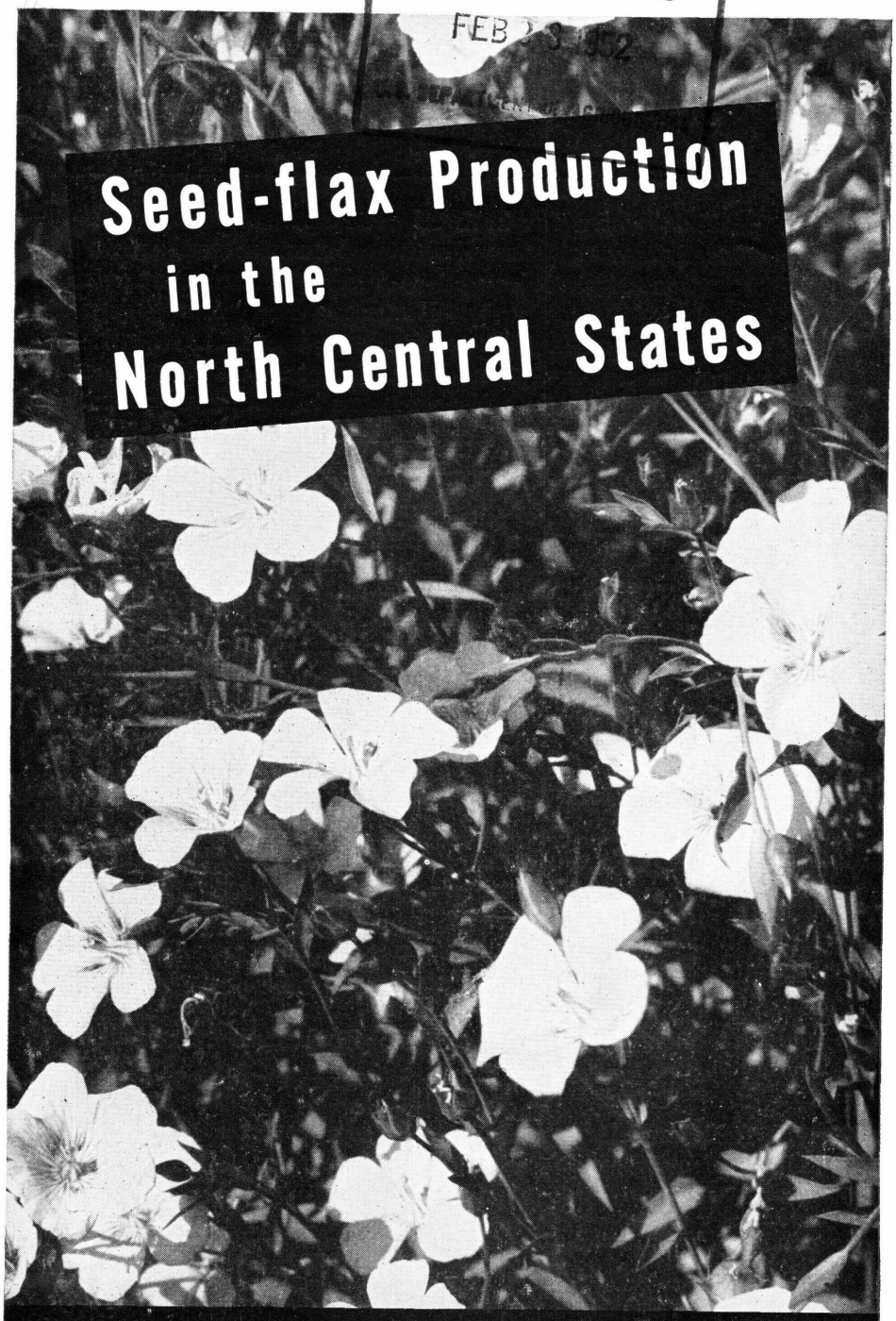

Seed-flax Production in the North Central States

Farmers' Bulletin No. 2036
United States Department of Agriculture

FLAX is grown for both its seed and its fiber. This bulletin covers the production of flax for seed in the North Central States and Montana, where the crop is grown most extensively. Formerly flax was grown chiefly on new lands, but with the development of wilt-resistant varieties it is now possible to grow it on the same land in short-time rotations with other crops. Many of the newer varieties are also rust-resistant, so that losses from this disease have been reduced greatly in recent years.

It is important to grow flax on clean land. Flax does well following corn that has been given thoroughly clean cultivation. A rotation that includes (1) a small-grain crop; (2) a legume crop, such as sweetclover, red clover, soybeans, or field peas; (3) corn or other intertilled crop; and (4) flax, is very satisfactory.

Flax is a cool-weather crop. As a rule, it should be sown early to enable the plants to complete most of their vegetative growth in the cooler weather of early summer.

Flax for seed production is sown at a rate of 3 to 4 pecks (42 to 56 pounds) to the acre in Minnesota, but at a somewhat lower rate in the drier western part of the Great Plains flax-producing area. Only clean, sound, and treated seed should be planted. A good stand of early-sown flax helps control the growth of later starting weeds.

Recently developed chemical sprays have proved useful in the control of certain broadleaved weeds in flax fields.

This bulletin supersedes Farmers' Bulletin 1747, Flaxseed Production in the North Central States.

Washington, D. C. Issued January 1952

SEED-FLAX PRODUCTION IN THE NORTH CENTRAL STATES [1]

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INTRODUCTION

THE FLAX PLANT (*Linum usitatissimum* L.) is the source of two valuable products, flaxseed and fiber. Two distinct types of flax are grown, depending upon whether the seed or the fiber is the principal product desired. This bulletin treats of growing the crop especially for the seed, from which linseed oil is made.[2] The coarse straw of seed flax usually does not yield a fiber suitable for spinning. Some fiber is obtained from seed-flax straw; this fiber is used in the manufacture of cigarette and other high-quality specialty papers. Smaller quantities are used for padding upholstered furniture and in the manufacture of insulating material and wallboard. Recent studies in Minnesota show that a fiber satisfactory for linen can be produced from seed-flax straw by chemical methods. The process requires considerable modification of the usual methods of growing and handling the crop; consequently it may not be economically feasible.

[1] Cooperative investigations of the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, and the North Dakota and Minnesota Agricultural Experiment Stations.

[2] Fiber flax is grown in the United States only to a limited extent. Information on the production of fiber flax in the United States is given in U. S. Dept. Agr. Farmers' Bul. 1728, Flax-Fiber Production.

Flax is an annual plant that grows to a height of 12 to 40 inches. It has a distinct main stem and a short taproot. The slender root branches may extend to a depth of 3 to 4 feet in light soil. In thick seeding, as for fiber flax, only the main stem develops, whereas in thin stands 2 or more branches may develop from the base of the plant. The flax flower has 5 petals and a 5-celled boll, or capsule, which when filled contains 10 seeds, but not more than 10 except in abnormal double bolls.

Flax normally is self-pollinated; there is very little natural crossing. Individual flowers open at sunrise on clear, warm days, and the petals usually fall before noon. The petals are blue, pale blue, white, or pale pink, depending on the variety. The seeds usually are light brown, although in certain varieties they are yellow, mottled, greenish yellow, or nearly black.

Flaxseed yields from 32 to 44 percent of oil, based on dry weight. In commercial crushing about 19 pounds, or 2½ gallons, of oil is obtained from a bushel (56 pounds) of seed. Part of the oil, 3 to 6 percent, remains in the cake. The yield of oil varies with the type or variety of flax and the climatic conditions under which the crop is grown. If drought occurs when the seed is filling, that is, within 25 days after blossoming, the seed may be shrunken and the oil content low and of poor quality.

High temperatures, which often accompany a period of drought, are especially injurious to flax, because they reduce the yield and result in seed of lower oil content and lower iodine number. The iodine number is obtained by a chemical test; it indicates the drying quality of the oil, or, more exactly, the quantity of oxygen the oil will absorb in drying to form the protective film characteristic of good paint. The higher the iodine number of the oil, the better the drying quality. Oil from flax usually ranges from 160 to 190 in iodine number. In general, large-seeded varieties yield a higher percentage of oil than do small-seeded varieties. On the other hand, the small-seeded varieties may produce oils of a somewhat better drying quality, as indicated by a higher iodine number.

HISTORY OF FLAX IN THE UNITED STATES

Flax for fiber was one of the first crops introduced from the Old World. In colonial times nearly every household had its patch of flax, and flax continued to be grown to some extent for home use as late as 1840. Crushing and processing linseed oil from flaxseed began in the United States as early as 1805.

Until about 1920 flax was a pioneer crop in American agriculture, the center of production always being near the frontier, where new land was available. The census of 1850 showed Ohio and Kentucky to be the leading flax-producing States, but in 1900 North Dakota produced the most flax. During those 50 years the crop had migrated with the advance of settlement from Ohio, across Indiana, Illinois, Iowa, and Minnesota, to North Dakota. This shift in areas of production was caused partly by the injurious effects of flax wilt in the older cultivated lands, but chiefly by the greater economy of production in the fertile virgin soils of the northern Middle West.

In more recent years flax production has continued largely in western Minnesota, eastern North Dakota, and northeastern South Dakota,

with smaller areas in Texas, Montana, California, and Arizona. Substantial acreages were grown in other areas, especially during and immediately following World Wars I and II.

In most years flax production in the United States has been insufficient to meet the requirements of domestic industries, and large quantities of flax have been imported, chiefly from Argentina. The tariff act of 1922 provided for a duty of 40 cents a bushel on imported flaxseed and 3.3 cents a pound on linseed oil. In 1930 this was revised to provide for a duty of 65 cents a bushel on flaxseed and 4.5 cents a pound on linseed oil. This remained in effect until November 1941, when the duty was reduced to 32.5 cents a bushel (rate on oil not reduced), a reduction made possible by Presidential proclamation under amendments to the tariff act authorized by Congress for fostering reciprocal trade agreements. This tariff rate applies to imports from all countries and continues in effect until it is terminated by Presidential order.

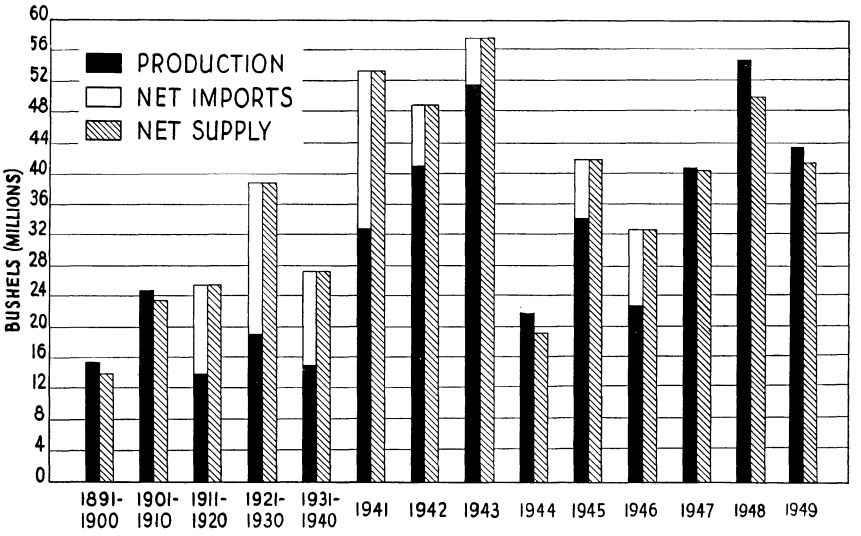

FIGURE 1.—Flaxseed production, net imports (including linseed oil in terms of seed), and net supply in the United States for the period 1891 to 1949.

The annual production, net imports (excess of imports over exports), and net supply available to industry in the United States from 1941 to 1949, with average data by 10-year periods previous to that time, are shown in figure 1.

THE FLAX-GROWING AREA

About 85 percent of the flaxseed acreage in the United States in 1949 was in Minnesota, North Dakota, South Dakota, Iowa, and Montana. About 12 percent was in California, Texas, and Arizona, where most of the crop is sown in the fall or early winter. The remaining 3 percent of the acreage was in 10 other States (fig. 2).

The concentration of the acreage in the North Central States and Montana has been due largely to conditions favorable to flax growing, such as moderate summer temperatures and sufficient, but not exces-

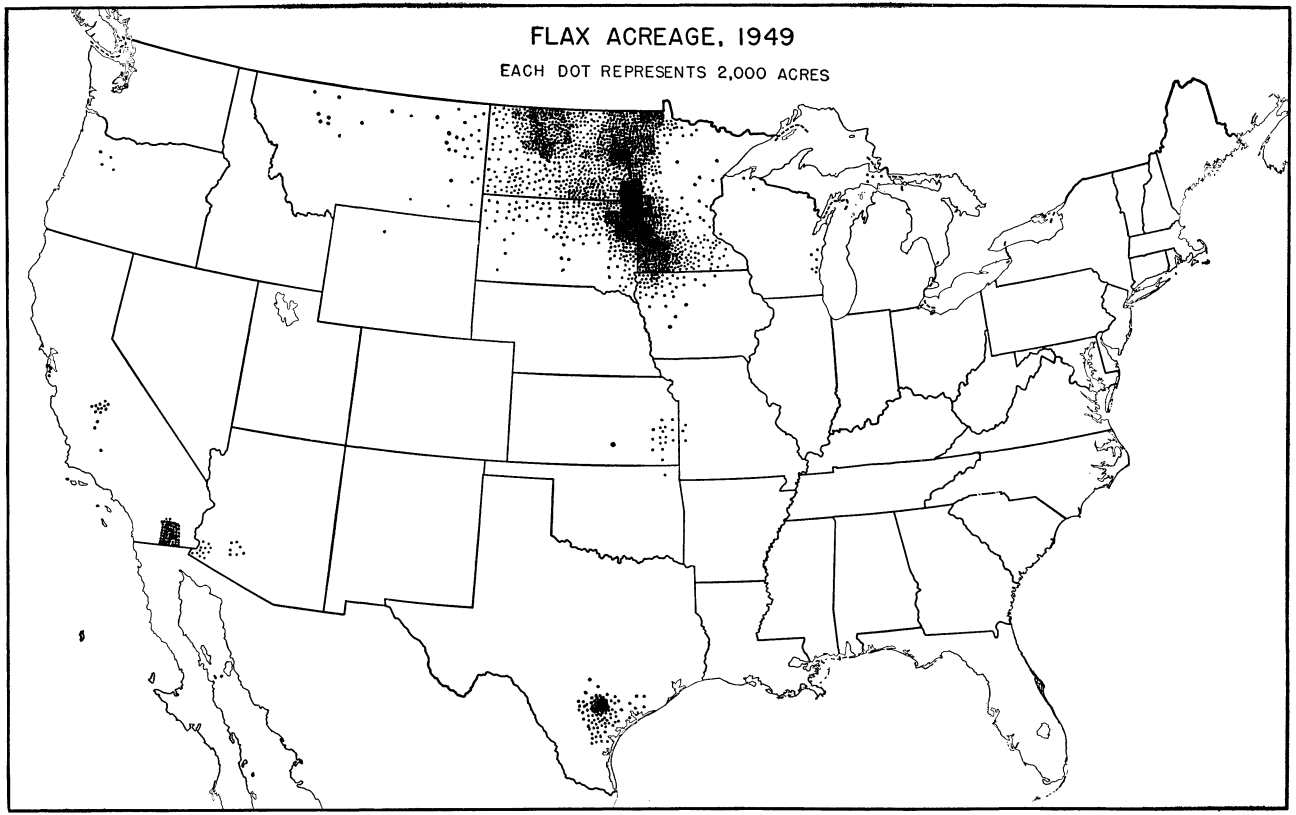

FIGURE 2.—Distribution of flaxseed production in 1949. Each dot represents 2,000 acres. Estimated area, 4,880,000 acres.

sive, rainfall to assure a good yield. A second factor has been the large acreage of fertile land suitable for flax. The annual rainfall ranges from 30 inches in parts of Minnesota down to 15 inches in eastern Montana. More important than total rainfall is the amount of precipitation that falls during the growing period. The warm-season rainfall ranges from 22 inches in Minnesota to 10 inches in Montana. Adequate moisture and relatively cool temperatures, particularly during the period from blooming to maturity, seem to favor both high oil content and high oil quality. In general, flax yields tend to decrease as precipitation diminishes. An excess of rain, however, may lead to lush growth, increased weed competition, and more favorable conditions for the development and spread of destructive diseases.

Flax is not a dependable crop in the dry-farming area of the central and southern Great Plains, because of high temperatures and limited rainfall. Good yields are obtained in occasional relatively cool moist seasons. If flax growing is attempted in this area, it should be sown only on land where weed competition will not be serious and when a plentiful supply of soil moisture is available in the spring. Also, it should be sown early enough to mature before the excessive heat of summer.

An increasing acreage of flax is being grown in Texas, where it is sown in November and December and makes considerable growth during the winter if enough moisture is available. The crop matures in May and is harvested before summer temperatures become excessively high.

A large acreage of flax is grown in California and Arizona as a fall-sown crop under irrigation. Excellent yields have been obtained in these States, as both temperature and moisture are usually favorable during the flax-growing season. Flax, however, must compete with more intensively cultivated crops that produce high acre returns. Its future production in this area will depend on the relative net income from flax and the other crops that the grower might choose.

USES AND MARKETS

Seed flax is grown principally for the oil extracted from the seed. Linseed oil has many uses in industry, some of the principal ones being for the manufacture of paint and varnish, linoleum, oilcloth, printer's ink, patent leather, and imitation leather, and as a core oil in making sand forms for metal casting.

In the manufacture of linseed oil, flaxseed is first ground to a fine meal. The meal is then heated and the oil extracted by heavy pressure. The extraction may be of the intermittent type, in which a hydraulic press is used, or of the continuous type, where the meal is fed in a continuous stream into an expeller press. In the continuous type, the meal is forced through a passage that becomes continually smaller. Thus heat and pressure are built up to expel the oil.

Chemical solvents have been used to extract the oil, but have been discontinued in most places because of the fire hazard. With the recent development of safer methods of handling them, however, interest in solvent extraction is being revived.

After the oil is extracted from the seed, the remaining linseed cake is prepared for livestock feed, either by grinding to linseed meal or

by making pellets suitable for feeding in outdoor feed lots or on the range.

The principal markets for domestic flaxseed are Minneapolis and Duluth, Minn. Most of the seed marketed in Minneapolis is processed there; that received at Duluth is shipped east on Great Lakes steamers—destined for mills at Chicago, Ill., Buffalo, N. Y., Philadelphia, Pa., and Edgewater, N. J., and in the vicinity of New York City. The west-coast mills—at Portland, Oreg., and San Francisco, Los Angeles, and Long Beach, Calif.—crush flaxseed produced in the area together with any imported seed that reaches the west coast. Linseed mills in Montana, North Dakota, Iowa, Kansas, and Texas also crush domestic seed.

Flax straw from flaxseed varieties is used in the manufacture of upholstery tow, insulating material, rugs, twine, and paper. The development of a new industry—processing the fiber for the manufacture of cigarette and other high-grade papers—has given a new market for some of the better quality flax straw produced in the more humid sections of the North Central States and for some of the straw produced under irrigation in California.

Flax straw, to be of value to processors, must be available in quantity and relatively free from weeds and from weather damage. Both environment and variety seem to influence the fiber characters of flax straw. Straw produced under dry conditions is shorter and is of less desirable quality than that grown with adequate effective rainfall. Rust, wilt, pasmo, and other diseases lower the quality of the fiber. Preliminary tests indicate that the straw of different varieties differs in the yield of fiber and efficiency of decortication. Some of the better varieties for fiber are Redwing, Dakota, Redwood, and Koto. Crystal and Minerva are regarded as definitely inferior in fiber characters.

The yield of straw varies chiefly with the amount of soil moisture available. In most areas the yield approximates one-half to three-quarters of a ton an acre of marketable straw. Flax straw is frequently sold under contract with processing plants. Sometimes farmers bale the straw and deliver it at a specified point, or the processor may buy the straw in the stack or in the swath after combining. Because the value of the straw is low compared to that of the seed produced, the choice of a variety for any given area should depend mainly on the ability of the variety to produce good yields of high-quality seed.

VARIETIES

Fiber flaxes are tall, mature early, and have small seeds. As flax for fiber is sown thickly, the stems are slender and without basal branches. Fiber flax is never grown primarily for oil. Seed that is not required for sowing the fiber crop, however, is sold on the market for crushing. Tests for 3 years at the Minnesota Agricultural Experiment Station showed that seed from fiber varieties averaged about 2 percent less oil than did commonly grown seed-flax varieties. The iodine number of the oil from the seed of fiber flax is acceptable.

The seed-flax, or linseed, group consists in general of six more or less distinct types. (1) Wilt-resistant, short-fiber; (2) common, or "Russian"; (3) Argentine; (4) Indian; (5) Abyssinian; (6) Golden, or yellow-seeded. There are a few others of minor commercial importance.

Nearly all varieties now grown commercially in the United States belong to the wilt-resistant, short-fiber type. Many of the varieties first recognized were developed by selection on the basis of wilt resistance and satisfactory seed yield. N. D. R. Nos. 52 and 114, the first of these, came into general use during 1910–20. These were followed by Linota, Chippewa, Winona, Redwing, Buda, and Bison. Bison came into extensive use between 1930 and 1941.

More recently, varieties that are resistant to both wilt and rust have been developed through hybridization. Among the first of these was a yellow-seeded variety, later grown under the name of Viking (or Golden), and Walsh, a large, brown-seeded variety. Viking (Golden) produces high seed yields, high oil content, and high iodine number, but has short straw and is very susceptible to pasmo. It came into extensive use in eastern North Dakota and Minnesota, following severe rust injury to Bison in the years 1941–43. However, Viking (Golden), in turn, suffered a serious set-back from pasmo injury in 1943 and soon was replaced by other rust-resistant varieties more tolerant to pasmo and satisfactory in other plant characters. Walsh, while satisfactory in rust resistance, lacked ability to yield well, except when conditions were especially favorable. Hence, it never came into extensive use.

Other varieties, developed for resistance to rust and wilt, were released to farmers about 1943. They include Koto, Renew, Victory, B5128, and Crystal. Varieties since released and grown in the north-central region include Sheyenne and Dakota developed and released in North Dakota, Minerva in Minnesota, and Arrow in Montana. In 1950 and 1951, Redwood and Marine, new rust-resistant varieties developed in Minnesota and North Dakota, respectively, were increased for release. After the release of Koto, Renew, Dakota, and Arrow, they were attacked by certain races of rust; and because of the increasing prevalence of these races in the North Central States, they should no longer be regarded as rust-resistant in that region. Each of these varieties has some merit and is therefore better suited to some conditions than others. They differ in time of maturity, disease resistance, plant type, flower and seed color, seed size, capacity to yield, oil content, and iodine number. Some of the more important agronomic and disease-resistant characters are compared in table 1. Most of the varieties are sufficiently wilt-resistant for farm production, provided a good rotation is followed. The varieties listed as having excellent rust resistance have been either immune or highly resistant in the North Central States. None of the varieties has satisfactory resistance to pasmo. Crystal and Marine seem most tolerant; Viking (Golden) is the most susceptible.

GROWING THE CROP

CHOICE OF LAND

The selection of land suitable for flax production is highly important. Only land that seems likely to produce a good yield should be sown to flax. In the corn-growing area of Minnesota and the Dakotas, land that will grow good corn is usually considered suitable for flax, provided it is not too foul with weed seeds. To the north and west of the Corn Belt, flax is usually grown on the types of soil used for

TABLE 1.—*The leading flax varieties classified with respect to some plant and seed characters and to their reaction to important diseases (listed in order of maturity)*

Variety	Color		Seed size	Relative maturity	Resistance to disease [1]		
	Blossom	Seed			Wilt	Rust	Pasmo
Redwing	blue	brown	small	early	fair	fair—	Fair.
Sheyenne	do	do	medium	do	very good	excellent	Do.
Marine	do	do	do	midearly	good	do	Fair+.
Renew	do	dark brown	do	do	fair	poor [2]	Poor.
Dakota	do	brown	do	do	good	do.[2]	Fair—.
Koto	do	do	do	do	very good	do.[3]	Fair.
Bison	do	do	medium+	do	do	do	Do.
Arrow	do	do	medium	do	do	fair—	Do.
Buda	do	do	small	midlate	do	do.—	Do.
Viking (Golden)	pink	yellow	medium+	do	fair	excellent	Very poor.
Walsh	blue	brown	very large	do	do	do	Poor.
Crystal	white	dark yellow	medium+	do	do	do	Fair+.
Victory	do	brown	large	do	good—	good [4]	Poor.
Rocket	blue	do	medium+	do	fair	excellent	Do.
Royal	do	do	do.+	do	do	fair+	Fair—.
Redwood	do	do	do.+	do	good—	excellent	Do.—.
Minerva	do	dark yellow	do.+	late	good—	good—	Fair.
B5128	do	brown	large	do	good—	excellent	Do.

[1] Reaction to the races now common in the North Central States. No flax variety has satisfactory resistance to pasmo.

[2] Immune to all common races until 1948. Races to which it is not resistant were increasingly common in 1949–51. Where these races now occur the variety's resistance would be classed as poor.

[3] Immune to some common races, but susceptible to many. For the races to which Kota is susceptible, its resistance would be classed as poor.

[4] Victory is a mixture of lines, some of which are susceptible to races of rust now occurring in the North Central States.

wheat or barley. Land foul with weed seeds, poorly drained, or subject to excessive drought damage should not be sown to flax.

Special attention should be given to fitting flax into the cropping sequence. Where corn is a crop of major importance, a considerable acreage of flax is sown following corn. Flax usually yields satisfactorily when sown after small grain if the stubble has been plowed under in August, but in some regions corn competes strongly for such land. Where moisture conditions are favorable, yields of flax following alfalfa or sweetclover are frequently good, but the added nitrogen may stimulate weed growth to such an extent that harvesting is difficult. In the drier sections alfalfa and sweetclover land is often low in moisture reserves and flax that follows these crops may suffer from drought.

Ordinarily, flax does not do well on loose soil following potatoes or sugar beets, especially on old lands that are likely to be foul with weed seeds. Digging these crops brings weed seeds to the surface, where they germinate readily the following spring. It is, therefore, usually better to follow potatoes or beets with a crop that grows more vigorously than flax.

A rotation or cropping system that includes a legume or a mixture of a legume and grass is usually beneficial to flax. It insures a soil high in available fertility and in root fiber and organic matter, which promotes better tilth. Such soil is less subject to crusting and has a larger capacity for absorbing and holding moisture. The most favorable rotation differs with individual farms, soil conditions, number of animals kept, need for feed and forage, and other factors that influence the kind and proportion of the crops to be grown.

PREPARATION OF SEEDBED

Regardless of the kind of soil or the previous cropping, certain objectives should be kept in mind in preparing the seedbed—(1) control of weeds; (2) conservation of soil moisture; (3) proper disposal of stubble or trash; and (4) a firm seedbed.

Whether fall or spring plowing of small-grain stubble land is better for flax depends upon the conditions under which the crop is grown. In the humid areas and on heavy soils of the northern States, early fall plowing and early spring sowing generally are considered best. Plowing or disking stubble land in August stimulates the germination of weed seeds in the fall where moisture conditions are favorable. Frosts kill the weeds, but the dead plants, if large enough, hold the snow and prevent soil blowing.

In the drier sections of the Great Plains fall rains may be too light to induce weed seeds to germinate. Here, a winter cover of stubble or trash will catch and hold the snow, thus conserving valuable moisture and helping to prevent soil erosion. Under such conditions, especially on the lighter soils, spring plowing frequently gives the best results. In the Great Plains spring-plowed land is usually freer from weeds than land plowed in the fall. Working the seedbed with a harrow or packer immediately after spring plowing tends to conserve soil moisture. In these drier sections it is often the practice to plow, prepare the seedbed, and sow the flax in a single operation. This places the seed in moist soil, so that germination is uniform and rapid, thus giving the crop a better chance to compete with early-starting weeds.

The depth to which land is plowed or tilled may be an important factor in weed control. If a crop of weed seeds has been turned under at the previous working, deep tillage at the time of soil preparation may bring some of the dormant seeds to the surface where they may germinate and create a serious weed problem in the flax crop.

Pasture or sodland that is to be seeded to flax the following spring preferably should be plowed during the summer to allow the sod to settle and decay. Sodland broken in the spring after the grass growth has started should be packed with a heavy packer, or with disks set nearly straight, to make the surface firm. Such land should be prepared as soon as possible after breaking in order that the seed may be sown before the turned sod becomes dry. Plowing, harrowing or packing, and sowing often are done in one operation.

Land from which corn is harvested in the field usually should be plowed. This buries the stalks so that they do not interfere with seeding or harvesting. Where corn borers are prevalent it is even more urgent to plow under the stalks. A heavy disking may be satisfactory where corn borers are absent, and a light disking of the stubble is sufficient where the cornstalks have been harvested for silage or fodder. Disked land should be harrowed before the flax is sown.

Flax germinates at a lower temperature than many of the grassy weeds that may become troublesome later. If the seedbed has been well prepared and is firm, it will insure sowing at the proper depth and will result in prompt and more uniform germination of the flax, thus allowing the crop to get started before the weeds.

METHOD OF SOWING

Flax should be sown with a grain drill rather than with a broadcast seeder. Drilling results in better distribution and more uniform depth for the seed, which results in a more satisfactory stand. The seed should be sown at a depth of 1 to 1½ inches. A drill with press at-

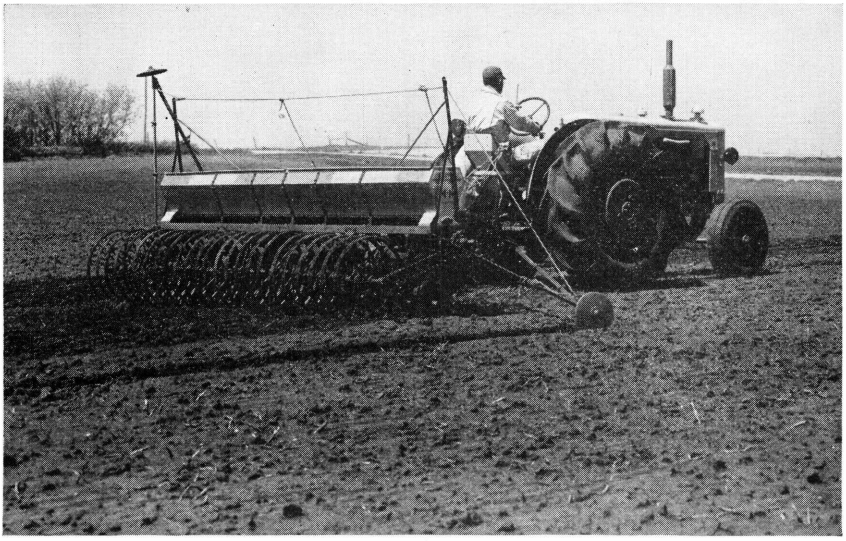

FIGURE 3.—Seeding with press drill on a firm seedbed.

tachments (fig. 3) is most satisfactory because it will press the moist soil about the seed to insure prompt and even germination. If the drill does not have a press attachment, a soil packer may be attached behind the drill, or the field may be packed in a separate operation immediately following sowing. When it is necessary to sow in loose soil, the pressure springs of the drill must be released and the weight of the disks depended upon to place the seed at the proper depth.

TIME OF SOWING

Carefully conducted experiments, as well as farmers' experiences, show that early spring sowing generally produces the most satisfactory stands and the highest yields. Early sowing allows the crop to make a larger part of its growth in the cool weather of spring and early summer when soil moisture is likely to be more plentiful. Experiments in North Dakota and Minnesota indicate that flax sown in late April or early May usually yields best. For best development flax requires cool weather at the time of blooming and ample moisture and moderate temperatures until nearly ripe. Such conditions are more likely to prevail when flax is sown relatively early than when sown late. In general, flax should be sown at the time suitable for sowing spring wheat or immediately afterward.

Light frosts seldom injure flax in the seedling stage. Seedlings just emerging seem most tender, but even these will withstand a moderate frost, especially if the soil is moist and they are not injured further by drying winds. After the plants are 2 or 3 inches high and are hardened by exposure, they may endure temperatures as low as 18° F. for a short time without serious injury. The degree of injury from freezing varies with the minimum temperature, the condition of the plants, the soil-moisture supply, and the weather conditions both before and after freezing.

When late sowing is unavoidable, seeding flax the first week of June gives fair assurance that the crop will ripen before frost. Later sowing often results in low yields, even though the crop may escape frost. With late sowing, an early-ripening, disease-resistant variety, such as Sheyenne, Marine, or Redwing, may give fairly good yields, although not so good as with an earlier sowing.

Flax in the green-boll stage is easily injured by heavy frosts, which may occur late in the summer or at high altitudes. The green seeds, which contain from 50 to 75 percent moisture, may be killed by freezing temperatures that do not kill the leaves and stems. In Minnesota a delay of 10, 20, or 30 days after the first practical sowing date resulted in yield losses of 22, 23, and 47 percent, respectively.

Yields from flax sown at intervals of 10 to 15 days from April 20 to June 10 in North Dakota are shown in table 2. In eastern North Dakota flax sown between April 20 and May 10 yielded about equally well; later sowings, less consistently. Sowings on May 20, June 1, and June 10 yielded 12, 33, and 60 percent, respectively, less than sowings on May 1. Average yields and the difference between average yields were less in western than in eastern North Dakota, owing partly to drought and Russian-thistle.

TABLE 2.—*Average yields, in bushels per acre, obtained in date-of-sowing trials with flax at 3 stations in North Dakota*

Date sown [1]	Fargo, 1919–26 (8 years)[2]	Mandan, 1917–31 (14 years)[3]	Dickinson	
			1923–27 (4 years)[4]	1928–43 (11 years)[5]
April 20	15. 3	4. 0	3. 5	6. 7
May 1	15. 8	4. 6	4. 7	6. 9
May 10	16. 0			5. 3
May 20	14. 0	4. 8	5. 1	4. 8
June 1	10. 7	4. 1	5. 4	3. 4
June 10	6. 3	3. 0	2. 3	1. 5

[1] Dates approximate only. At Dickinson previous to 1928 and at Mandan previous to 1926, sowings were at 2-week intervals; April 20 would be about April 15; May 20, about May 15; and June 10, about June 15.

[2] In 1927 the earliest sowing possible was April 28, yield 20.2; May 7, 21.6; May 20, too wet; May 30, 14.3; and June 10, 11.2 bushels per acre.

[3] Complete failure in 1921. Trials for 3 sowing dates 1914–16: May 1, 19.1; May 15, 18.7; and June 1, 16.2 bushels per acre.

[4] Average of 5 trials with different soil preparation. Crop failed in 1925.

[5] Trials abandoned in 1933, 1935, 1936, 1937, and 1938.

Deferred sowing may be necessary where early-starting weeds, such as wild oats or Russian-thistle, are most abundant. Early tillage of such land helps to promote early germination of weed seeds, allowing the young plants to be destroyed by subsequent tillage. Sometimes two or more crops of weeds may be destroyed in this manner, but sowing must then be deferred until late May or early June. On the other hand, when weeds like green and yellow foxtail (pigeongrass) are prevalent flax should be sown early, so that it may become established before such warm-weather weeds get started. It is usually better, however, not to sow flax on land foul with weed seeds.

RATE OF SOWING

The usual rate of sowing flax is about 2 pecks (28 pounds) an acre in Montana and the western Dakotas, 2½ to 3 pecks (35 to 42 pounds) in North Dakota and western Minnesota. In eastern Minnesota, with greater rainfall, it is considered advantageous to sow 3 pecks (42 pounds), or even 1 bushel (56 pounds), to the acre. The heavier rate of sowing insures a fuller stand and may help control weeds. Less seed is required to give a satisfactory stand on seedbeds favorable for prompt and even germination than on seedbeds where soil conditions are less favorable. The foregoing rates of sowing are recommended for varieties, such as Bison, with medium-size seed. The rate may be slightly reduced for a small-seeded variety, and increased for a large-seeded type, such as Victory or B5128.

More uniform stands of flax frequently follow the use of a suitable seed disinfectant, such as New Improved Ceresan or Ceresan M, to control seed-borne diseases. Dry seed may be treated several weeks in advance of sowing without injury to the germination of the seed. The beneficial effect of the seed treatment is heightened if the seed is treated at least 24 hours before sowing.

Drug stores, seed houses, and other places dealing in seeds and similar products sell seed-treatment compounds. United States Department of Agriculture Miscellaneous Publication 219, Treat Seed Grain, gives information on seed treaters and how to use them on seed flax.

FLAX-WHEAT MIXTURE

Sowing flax and wheat as a mixed crop is not a common or generally recommended practice. Experimental sowings show that on reasonably good land flax sown alone, or wheat sown alone, usually yields more satisfactorily than the mixture. This is especially true for flax.

Sowing a mixture requires a larger outlay for seed, as flax is usually sown at about the normal rate, with the addition of wheat in varying amounts. The stand and yield of flax obtained are reduced in direct proportion to the amount of wheat used in the mixture. Sowing wheat in excess of 30 pounds an acre, in a mixture with flax at about the normal rate for that crop, will result in a low flax yield. Therefore, if the mixture is to be sown and a reasonably good flax yield is desired, the amount of wheat in the mixture should not exceed 30 pounds an acre, and less, as low as 15 or 20 pounds, would be preferable. Varieties that will mature at about the same time should be chosen.

The two crops may be sown together if the flax is not sown too deep, or they may be sown in separate operations. If sown separately, cross seeding affords a better distribution of plants. It is doubtful, however, if enough is gained to warrant the extra cost of two seeding operations. Mixed flax and wheat will at times result in a slightly higher total yield from a given area of land. Offsetting this, however, is the higher cost of seed and the cost of separating the two crops after threshing and before marketing.

HARVESTING

Flax plants should be fully ripe when cut, unless unusual conditions make it impracticable. Fully ripe flax dries quickly in the shock, bunch, or swath. If sown late, or if the fall is wet and cool, flax may continue to bloom until frost. Under these conditions it is advisable to cut the crop when a large proportion of the bolls are ripe, even though the stems are still green.

Flax may be harvested with a grain binder (fig. 4, *A*), or a swather (windrower) (fig. 5), or by direct combining. When flax cut with a binder is shocked the bolls are kept from the damp ground and the seed is usually not damaged. Small or long, narrow shocks should be built to allow good ventilation (fig. 4, *B*).

The cost of harvesting flax has been materially reduced by the use of the combine. When the swather is used the crop in the swath is in condition to thresh after a few days of dry weather (fig. 5). Direct combining is the cheapest method and is entirely satisfactory when the flax is thoroughly dry and free of weeds. However, this is a less common practice than swathing because few fields are free of weeds and few ripen uniformly.

In late fields in Montana and North Dakota, harvesting sometimes is delayed until frost has killed the weeds. The weeds dry rapidly after being frozen, and the flax can be harvested with a combine within

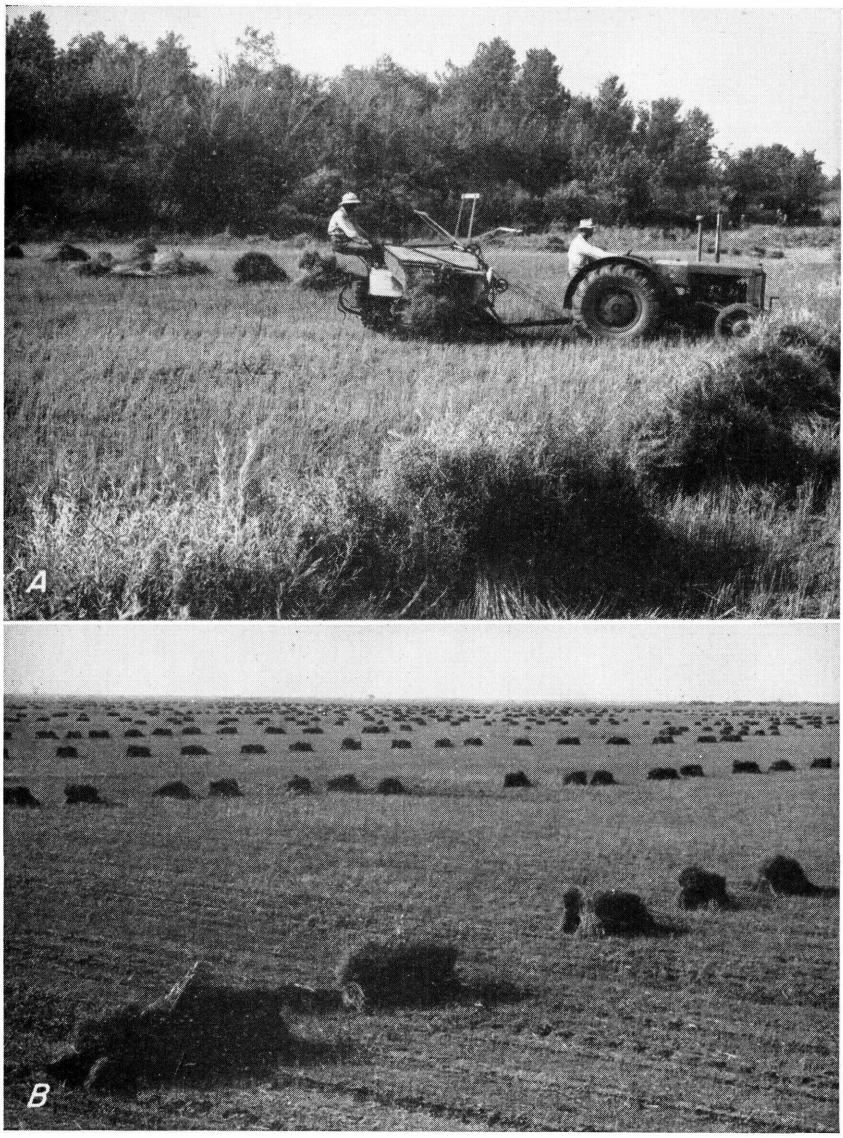

FIGURE 4.—*A*, Harvesting seed flax with a grain binder in Minnesota; *B*, narrow shocks that permit rapid drying.

a few days. Ordinarily, flax will stand for some time after ripening without loss from shattering. In very dry, hot weather, however, it may shatter somewhat. Therefore, delaying harvest until after frost can be recommended only when late flax need not stand too long.

The combine or the windrower often can be used to harvest flax that is too short to be cut with a grain binder. This advantage in the use of the combine, however, does not justify the growing of short-strawed varieties of flax, which are more difficult to harvest by any method.

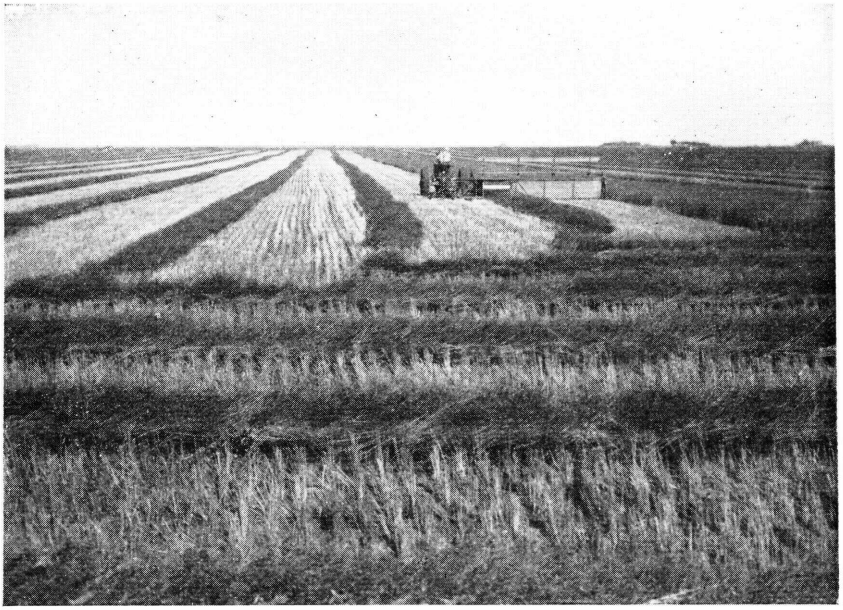

FIGURE 5.—Swathing flax. After drying for a few days a combine with pick-up attachment will be used to thresh the crop.

The seed coat of flax is injured easily when threshed, especially if the seed is unusually dry. It is advisable to use no more teeth in the concaves than necessary to recover all the seed, and the speed of the cylinder may be reduced slightly if the flax is very dry. Special types of cylinders that lessen seed injury are available for some machines.

CLEANING AND STORING THE SEED

Hundreds of cars of flaxseed shipped to market contain 10 to 40 percent of dockage, consisting of cracked flaxseed, other grains, weed seeds, and chaff. Except for the cracked flaxseed, these are mostly undesirable mixtures for crushing, but are of value for feed. Dockage, if present to any extent, should be screened from the flax before marketing. Although not many farms are equipped for such cleaning, an increasing number of local elevators have installed cleaning equipment to remove dockage, which is of value for feed. This feed is saved for use in the community, thus avoiding freight charges. Dockage containing weed seeds to be used for feed should be finely ground, so that viable weed seeds will not go into farm manure to be scattered about the farm.

In cleaning flax for seed, a steel-wire sieve with meshes 4 by 16 an inch (or 4 by 14 for large-seeded varieties) will separate the grain and the larger weed seeds from flax. A metal sieve with round holes one-fourteenth of an inch in diameter will remove most of the small weed seeds. The air blast should be regulated to blow out all immature and cracked flaxseeds and trash. Flax intended for seed should be recleaned before storage. Only dry, sound, plump seeds should be saved. This will reduce the spread of wilt, rust, and other diseases

that may be carried as spores on broken stems, chaff, and immature seeds. Flaxseed should be dry and stored only in a dry place. Air-dry flaxseed contains only 6 to 8 percent of moisture.

WEED CONTROL IN FLAX

Weeds are a serious handicap in the production of flax. The characteristic short growth and small leaves that make flax an especially good companion crop for grass seedings are responsible for its poor competition with weeds. Satisfactory practical control of weeds involves careful selection of the field to be sown and the use of both chemical and cultural practices. At present, dinitro and 2,4-D are used to kill selectively certain annual weeds that are growing in the crop. Neither chemical, however, kills grassy weeds, and at dosages safe for flax they are relatively ineffective on thistles and similar perennials.

The dinitros, of which Sinox W and Dow Selective are common examples, kill the weeds whose leaves are easily wetted. Broad-leaved plants with leaves that stand out in a relatively horizontal position are susceptible because they retain the spray long enough for adequate absorption. Plants with waxy leaves that are more or less upright are not killed, because the spray rolls off before it is absorbed. The selectivity of the chemical to flax is influenced by humidity, rain, and dew. Flax may be badly burned if sprayed when wet, when the soil surface is wet, when humidity is high, and when leaves are yellow. The effectiveness varies with temperature, so that the concentration to be used will also vary. For average use, 3 quarts of dinitro in 75 gallons of water an acre is recommended. At 65° F. this concentration probably will be too weak; at 85° F. or above, too strong. A test strip sprayed through the field can be observed in a few hours for results. If the flax is injured, a weaker concentration should be used; a poor weed kill in the test strip indicates a stronger solution is needed.

The dinitro weed killers may be used on flax underseeded with alfalfa or clovers, a practice not recommended for 2,4-D. The amount of water required for dinitro spray is considerably more than for 2,4-D. Experienced operators successfully use less than 75 gallons an acre with dinitros, but the risk of burning the flax is increased. The sensitivity of the dinitros to environmental conditions is also commonly considered a disadvantage. For best results the weeds should be small and the flax from 4 to 6 inches tall when sprayed (fig. 6).

Flax is less tolerant to 2,4-D than are the small grains. In experiments with weed-free flax the yield was reduced in proportion to the dosage of the 2,4-D spray. When mustard was present in the crop, the yield of flax was increased by spraying with recommended amounts of 2,4-D because the competition of the mustard was more injurious than the 2,4-D. Doses that are too large have reduced the yield of flax even when the weeds were killed. The use of 2,4-D for weed control in flax is advisable only when the loss from weeds is greater than that from the spray. For this reason, spot spraying is preferred to over-all applications unless weeds are generally distributed over the field.

FIGURE 6.—Time to apply 2,4-D or dinitro sprays—when wild mustard and other susceptible weeds are young.

The tolerance of flax varies with variety, time of application, and the formula of 2,4-D. Varietal differences are considerable. In experiments in Minnesota, an application of four times the amount of 2,4-D that reduced the yield of Crystal and B5128 did not injure Redwing. Minerva, Crystal, and B5128 are more susceptible to 2,4-D injury than Redwing, Redwood, Koto, Dakota, Royal, or Sheyenne. More attention to correct dosages and time of application is needed when spraying the more susceptible varieties. All varieties of flax are susceptible to injury when in bud or blossom. Before budding, they are affected most if sprayed when they are increasing rapidly in height. Flax should be sprayed as soon as there are enough susceptible weeds above ground to make spraying effective. Amine salts, sodium salts, and esters of 2,4-D can be used, but the esters are too strong for the susceptible varieties of flax. From 1 to 1.5 ounces of acid in the form of ester or 3 ounces of amine or sodium salt is recommended for killing susceptible weeds such as mustard; under favorable conditions from 1.5 to 2 ounces of ester or 4 ounces of amine or sodium salt will kill lambssquarters and pigweed.

Neither dinitro nor 2,4-D controls grassy weeds such as pigeongrass, barnyard grass, or wild oats. TCA (sodium salt of trichloroacetic acid) may be used at from 5 to 10 pounds per acre to kill these grasses except wild oats. It should be applied when the weeds are small. TCA and 2,4-D may be applied together if both grass and broadleaved weeds are present and in the proper stage for treatment.

Plowing grain stubble soon after harvest keeps many weeds from producing seed. Many weed seeds already in the surface soil will germinate if moisture is adequate, but the seedlings from them are killed by cold weather later. If the soil is not stirred too deep the following spring fewer weed seeds will be left to grow. Such land should be worked in the late summer soon after plowing to stimulate

weed-seed germination, and spring preparation of the seedbed should not be deeper than 3 or 4 inches. It may be advisable to sow oats after the stubble plowing where weeds do not provide enough ground cover to control erosion.

It is possible, but more difficult, to provide a clean surface in corn plantings. A clean soil layer for the flax crop that follows is possible only if the weed seeds are germinated and the seedlings killed before the corn is laid by. The land should be plowed early in the fall preceding the corn. The seedbed should be prepared early the next spring and cultivated frequently before planting. After emergence of the corn, and when it is well rooted, weeds in the hills or rows may be killed by harrowing. The clean land should not be plowed after removing the crop. If it is, the surface layer will be turned under and a new crop of weed seeds may be exposed.

In experiments in Minnesota, flax has yielded as well following oats that were plowed immediately after harvest and rough-worked as it has following corn that had been kept clean. Grassy weeds other than wild oats were controlled equally well by both methods. Wild oats were controlled best when fallow or corn was kept very clean the year preceding the flax. Wild oats were somewhat less effectively controlled when alfalfa and Sudan grass preceded flax. Control of wild oats was unsatisfactory in oats given postharvest cultivation or underseeded with alfalfa, or in winter wheat sown in September following a summer fallow.

DISEASES OF FLAX

Losses from diseases are largely responsible for the concept that flax is a risky crop. This idea developed when wilt-susceptible varieties were being grown. In recent years disease losses have been smaller in flax than in competing cereal crops. However, losses from disease are sometimes spectacular. Bison flax was heavily damaged by rust in northwestern Minnesota and eastern North Dakota in 1941, 1942, and 1943. In 1943, the rust-resistant Viking (Golden), which had largely replaced Bison, was severely damaged by pasmo in southeastern North Dakota and western Minnesota. In 1949, 1950, and 1951 some fields of Dakota, a heretofore rust-resistant variety, especially those sown late, were heavily infected with rust in the Red River Valley of Minnesota and North Dakota. Heavy infection and severe damage occurred also in some fields of Dakota flax in central North Dakota in 1950, and in 1951 it became widespread and destructive in North Dakota and Minnesota. The prevalence and destructiveness of a disease varies from one season to another, depending on environmental conditions, prevalence of particular races of the disease organism, and varieties grown.

Wilt, rust, and pasmo are the important flax diseases in the United States. Anthracnose; stem break, or browning; damping-off; seedling blight; and heat canker are widely distributed and occasionally destructive. In some years natural and mechanical injuries to flaxseed are responsible for poor stands.

WILT

Wilt (caused by *Fusarium lini*) may attack the flax plant in all stages of development. The roots of seedlings may be completely

rotted and the plants "damped-off." If older plants are attacked, although remaining upright, they may wilt rapidly and die or they may be stunted. The lower leaves may turn yellow and fall off. The main stem may be killed, and new, apparently healthy branches will develop from the base. Only a part of the stem may be affected; that is, a dead-brown infected streak may extend up one side in sharp contrast with adjacent green tissue. Premature ripening may be the only indication of a weak infection or a late attack.

Although flax wilt is spread from one section to another on infected seed or flax refuse, the fungus is now so prevalent in the soils of the flax-growing area of the North Central States that only wilt-resistant varieties can be grown successfully. Some varieties are highly wilt-resistant; others are only moderately so (table 1 and fig. 7).

FIGURE 7.—Harvesting the sixtieth consecutive crop of flax on plot 30, North Dakota Agricultural College, Fargo. This plot has been cropped to flax continuously since 1890 and only highly wilt-resistant strains can survive. (Photograph by W. P. Sebens.)

RUST

Rust (caused by *Melampsora lini*) first appears as bright-orange pustules on the leaves and stems of flax plants. Each pustule produces numerous spores that are readily carried by the wind to other flax plants, thus spreading the disease. Flax rust thrives best on young, vigorously growing plants, and a new crop of spores may be produced about every 10 days. Cool, moist weather favors rust development; hot, dry weather checks it. Late in the season, the orange pustules, especially those on the stem, enlarge and become dark brown to black. This is due to the formation of the thick-walled overwintering spores. In spring these resting spores germinate and infect the young flax plants.

In the North Central States, the rust overwinters on the old flax straw and stubble of the previous years. For this reason flax should not be sown on the same land 2 years in succession, or near fields of unplowed flax stubble. Good fall plowing that buries the straw

and stubble also aids in controlling the disease. The most effective control for rust is the use of resistant varieties. Crystal, Viking (Golden), Marine, Redwood, Rocket, Sheyenne, Walsh, and B5128 have been highly rust-resistant.

PASMO

Pasmo (caused by *Sphaerella linorum*) is primarily a disease of the maturing tissues of the flax plant. It first appears as yellow-brown circular lesions on the cotyledons (seed leaves) of young plants. Later the yellow-brown spots appear on older leaves at the lower parts of the stems. The stems are resistant when young and growing vigorously, but may be attacked when the plants begin to ripen. Stem lesions enlarge more or less rapidly, depending on the variety, and extend both up and down the stem and around it. In early stages of stem infection the presence of irregular bands of brown alternating with the uninfected green parts of the stems is a striking characteristic. The brown lesions run together as the plants ripen prematurely, and lesions may become much darkened by other disease organisms. Usually flax is not heavily infected until the plants approach maturity and the seed yield is not greatly reduced.

Pasmo overwinters on the infected straw and stubble. Therefore, proper crop rotation and plowing under or burning the refuse from the previous year's crop aid in controlling the disease. Although no variety is classed as resistant, many of them are so tolerant that they are not greatly damaged unless conditions are exceptionally favorable for the development of the disease. Crystal and Marine appear to be the most tolerant: Viking (Golden), Renew, Victory, Rocket, and Walsh are very susceptible.

ANTHRACNOSE

All parts of the flax plant are attacked by anthracnose (caused by *Colletotrichum lini*). In the North Central States it occurs chiefly as a seedling blight, reducing stands. In California, in wet seasons, heavy damage has resulted from leaf, stem, and boll infections in the maturing crop. It is a seed-borne disease that often kills the seedling before it breaks through the soil. Infected seedlings that emerge commonly have water-soaked lesions at the edges of the cotyledons, although lesions may appear on any part of the cotyledons. The lesions enlarge and produce spores that are spread by wind and rain. The spores are washed down the stems during rainy periods and form cankers on the seedlings at the soil line. Infected seedlings often break over at the canker and die.

As anthracnose is a seed-borne disease, the use of disease-free seed is the most effective control. Treatment of seed with New Improved Ceresan or Ceresan M, at the rate of 1 to 1½ ounces a bushel, is effective in reducing the damage.

STEM BREAK, OR BROWNING

Stem break, or browning (caused by *Polyspora lini*), is primarily a disease of seedlings and of maturing plants. It is seed-borne, and the circular gray to brown lesions appear first on the cotyledons. These lesions often enlarge and spread to the stem, where they produce a canker at the first node. The stem becomes brittle and is weakened at the cankered region and may break over, hence the name

stem break. Often the broken stem is not completely severed and the plants may partly recover, but the quantity of seed produced is low. The brown spots on leaves and stems of older plants resemble those of pasmo, but they are smaller and those on the stems usually occur at a leaf scar. The use of clean seed and seed treatment as recommended for anthracnose are effective control measures.

DAMPING-OFF AND SEEDLING BLIGHT

Seedling blight of flax is caused by a number of micro-organisms (especially *Pythium* spp., *Rhizoctonia solani*, and *Colletotrichum lini*) which are carried on the seed or are present in the soil. The fungi may rot the underground parts of the plant or kill the seedlings before they emerge; also the rotting of seed before germination is common.

At least three types of seed injury are commonly associated with poor field stands. The most common injury is the cracking, splitting, and chipping of the seed coat and even of the embryo itself during threshing (fig. 8). Another defect, which in some years is more common in yellow-seeded varieties and is of little importance in brown-seeded ones, is a split at the small end of the seed. The seed coat curls back at this point to make an opening somewhat like that of a fish's mouth. Often the opening and cracks are so small that they cannot be seen without the aid of a good magnifying glass, but they are big enough for fungi to enter. Damage of the third type results from weathering in the field.

Injurious fungi may grow on and into the seed during periods of moist weather after the flax is ripe. They may kill the seed or weaken it so that the seedlings are more susceptible to attack. Treatment of injured seed with a suitable chemical disinfectant, such as New Im-

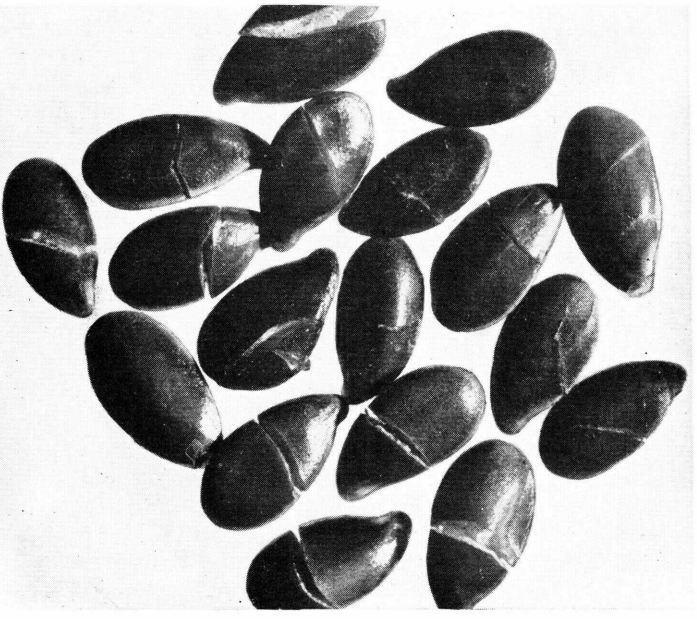

FIGURE 8.—Mechanical injury of flaxseed; sample magnified 6 times for close inspection.

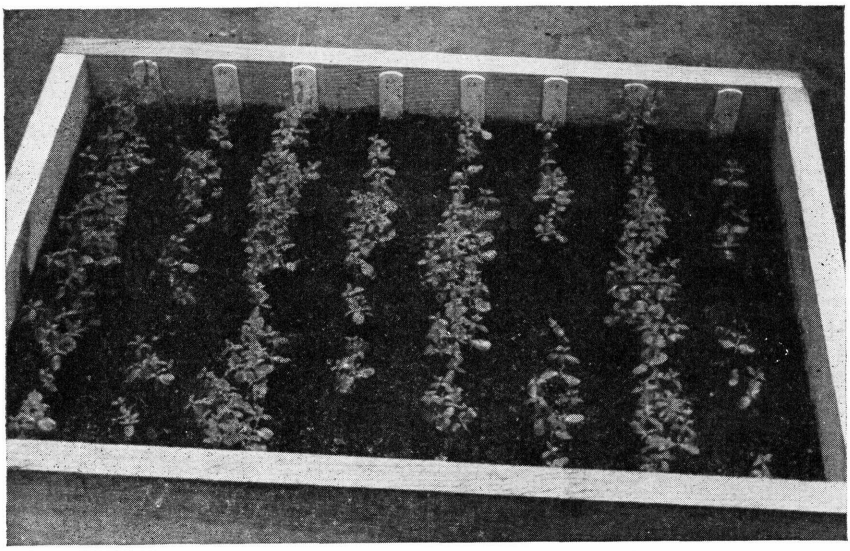

FIGURE 9.—Effect of chemical treatment of injured seed of flax. Four varieties, two rows of each variety (treated and untreated) with 100 seeds planted in each row.

proved Ceresan or Ceresan M, at the rate of 1 to 1½ ounces a bushel, may increase the stand greatly and help to prevent damping-off and seedling blight. Sound and disease-free seed usually performs better than treated damaged seed (fig. 9).

HEAT CANKER

Heat canker, a nonparasitic disease, often greatly reduces stands of flax, especially in semiarid regions. The high temperatures of the surface soil injure the plant tissues in contact with it. Thin stands and the formation of a surface-soil crust are conducive to heat canker. If the plants are injured when small, the stems at the ground line become sharply constricted, the tissues collapse, and the plants fall over and die. If plants are larger, the outer tissues are injured and the plants respond by producing additional cork tissue as an overgrowth adjacent to the injury. This wound tissue is brittle, and the plant may break off at the soil line during later stages of growth if exposed to strong winds. Early sowing and the sowing of sufficient seed to obtain shading of the ground are the most effective control measures for heat canker.

SUMMARY OF CONTROL

Flax diseases may be controlled or reduced by the following:

1. Growing resistant and recommended varieties.
2. Selecting sound and disease-free seed.
3. Treating seed with a suitable fungicide.
4. Planting early and using other good cultural practices.
5. Practicing sanitation and a good cropping sequence.

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